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SEMI-ANNUAL STATUS REPORT

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Grant NGL-05-002-007

for

1 April - 30 September 1969

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The present report covers the first half of the seventh year of operation under NASA Grant 05-002-007. Certain parts of the research previously supported by this Grant, namely these parts dealing with planetary physics and instrument development, are now supported by separate NASA Grants or contracts, and henceforth the activities in cosmic rays and interplanetary fields will also be separately supported.

The report is divided into a number of sections which describe the various activities, followed by a summary of staff, expenditures, and bibliography.

For the benefit of the reader who may not be interested in technical detail, the report opens with a brief summary of the various activities.

SUMMARY

I. Cosmic Rays (Vogt, Stone, Beuermann, and Fanselow)

This group's research program is directed toward the investigation of the astrophysical aspects of cosmic radiation and the radiation environment of the earth by means of particle-detector systems flown on spacecraft and balloons. The main efforts of the group have been directed toward the following three categories of experiments.

A. Experiments on NASA Spacecraft

1. A satellite experiment launched on OGO-2 on 14 October 1965, and on OGO-4 on 28 July 1967.

   This experiment, which is being carried out jointly by E. C. Stone at Caltech, J. A. Simpson at the University of Chicago, and C. Y. Fan at the University of Arizona, is measuring the time-dependent energy spectra of protons (1.2 to 40 MeV) and alpha particles (4 to 160 MeV). The observation of a new phenomenon was reported

in the Journal of Geophysical Research 74, 5127, 1969. The article describes the delayed access of solar flare protons into the center of the north polar region ($\Lambda > 80^{o}$) at a time when the proton flux at lower northern latitudes and in the south polar region was as much as a factor of ten larger. Other collaborative work with M. J. George and H. V. Neher is contained in George's doctoral dissertation, which is entitled "New Measurements on the Absolute Cosmic Ray Ionization from Sea Level to 1540 kilometers Altitude."

2. A satellite experiment launched on OGO-6 on 5 June 1969.
   This experiment is measuring the differential energy spectra of protons and alpha particles between 700 keV and 1 GeV/nucleon and of electrons between 1 MeV and 1 GeV. The differential measurements can be extended to 15 GV by using the geomagnetic field. This broad energy range will permit detailed studies of the solar modulation of galactic cosmic rays, the acceleration and interplanetary propagation of solar cosmic rays, and the penetration of charged particles into the magnetosphere. Although final data tapes are not yet available, preliminary quick-look data indicate that all elements of the 14-detector experiment are functioning properly.
3. A satellite experiment to be flown on IMP-H and -J in 1971 and 1972.
   This experiment is designed to measure the differential energy spectrum of electrons (0.18 to 2.8 MeV) and the differential energy spectra of the nuclear isotopes of hydrogen, helium, lithium, and beryllium (0.5 to $\sim$ 50 MeV/nucleon). This experiment will allow studies of solar and galactic cosmic rays and of magnetospheric acceleration of charged particles and the interrelation of those particles to the particles trapped in and precipitated from the magnetosphere. In support of this experiment, a 16-station monitoring system has been designed and built for use with the group's thermal vacuum system during the environmental tests of the surface barrier solid state detectors.
   The detailed engineering design of the prototype has been completed by the subcontractor who will also fabricate the experiment units.

4. A negatron-positron experiment proposed for Apollo Phase II.
   A proposal has been submitted to NASA in collaboration with D. A. Kniffen, T. L. Cline, C. E. Fichtel, and R. C. Hartman of GSFC, and P. Meyer of the University of Chicago. The proposed experiment is designed to measure the intensities and energy spectra of primary cosmic ray positrons and negatrons (7 to 300 MeV) in interplanetary space. The absence of atmospheric secondary contamination will permit a much cleaner measurement of primaries than is possible with a balloon-borne experiment.
   Caltech's contribution to the proposed experiment will include responsibility for the design, fabrication and testing of the fast electronics coincidence logic and the high voltage power supplies. A major part of this effort will be subcontracted.

B. Experiments performed with the NASA Balloon Program

Most of these experiments are either prototypes of experiments on existing or planned NASA spacecraft or they complement such observations.

1. A balloon-borne proton-alpha-electron (pαe) experiment which is essentially identical to the above OGO-6 experiment. The long range studies with the pαe detector system have been continued. A series of balloon flights were made during the 1969 Skyhook program at Ft. Churchill. These flights were of particular importance since they occurred simultaneously with polar passes of the equivalent detector system aboard OGO-6, thus allowing a direct derivation of the atmospheric secondary spectrum of nucleons from an intercomparison of satellite and balloon data, and studies of particle propagation in the magnetosphere.
2. A balloon-borne experiment with a high-energy electron spectrometer (~ 10 MeV to several GeV) utilizing counters and digitized spark chambers.
   The major part of the results from the 1967 observations with this instrument have been published in two papers: "Cosmic-Ray Electrons between 12 MeV and 1 GeV in 1967" (J. Geophys. Res. 74, 4701, 1969), and "Characteristics of the Diurnally Varying Electron Flux near the Polar Cap (J. Geophys. Res. 74, 4714, 1969).
   The studies initiated by this experiment are now being continued with the negatron-positron spectrometer (see below).

3. A balloon-borne magnetic spectrometer for the investigation of the energy spectra of negatrons and positrons in the 10-200 MeV/c momentum range. (See status report of 1 April 1968 - 30 September 1968 for a description of the instrument). This instrument was flown for the second season on four flights during the 1969 Skyhook program at Ft. Churchill.

   A number of major design improvements of this instrument are near completion. They include the incorporation of a larger bending magnet and a gas Čerenkov-counter.

   Data analysis of the 1968 flights has been continued. A paper on secondary electron production in the atmosphere is near completion. Further improved results on negatrons and positrons in the primary cosmic radiation were presented at the XI International Conference on Cosmic Rays, Budapest ("Cosmic-Ray Negatron and Positron Spectra observed near Fort Churchill in 1968") and will be published in the Conference proceedings. Extensive calibrations of the instrument for γ-ray induced interactions were performed at the Caltech synchrotron.

C. Experiments on Particle Accelerators

The OGO-6 and pαe detector systems (see above) use range versus energy-loss technique for the measurement of proton and helium energy spectra. Data so derived must be corrected for the interactions of the nuclei within the absorber stack used for range determination. Balloon and satellite instruments are not well suited for direct accelerator calibrations. An equivalent detector system and electronic logic therefore has been designed specifically for exposure to accelerator beams. The construction of this system is essentially complete and its first machine calibrations are presently rescheduled to begin in January 1970.

II. Cosmic Rays (Neher)

Work for this six month period on Physics 48 has centered around further analysis of the data from two polar orbiting satellites. Some of these results are incorporated into two papers which will soon be submitted for publication.

III. Interplanetary Fields and Plasmas (Davis)

The comparison of the theoretical and observational properties of the solar wind and interplanetary magnetic field has continued. The identification of the large amplitude, non-sinusoidal Alfvèn waves that dominate the observed fluctuations at least a third of the time has been strengthened by showing that the correlation between fluctuations in the magnetic field and in velocity holds for all three vector components whereas previously it had been demonstrated only for the radial components. It has also now been shown that there is a strong correlation between high plasma temperature and the presence of these waves; this supports the view that they are generated locally.

A final version of a paper with Dr. E. J. Weber on the angular momentum of the solar wind has been completed. It is now clear how the constants of integration are determined from the boundary conditions and why the observed angular velocity is observed to fluctuate so much.

Comparison of the Mariner IV magnetometer and plasma data taken near Mars in 1965 with the corresponding Mariner V data taken near Venus suggests that the interaction of the solar wind with Mars has much the same character as that with Venus. Hence Mars is unlikely to have a true magnetosphere but is likely to have a bow shock. Further observations near Mars would be valuable in exploring the degree of similarity and revealing the characteristics of this largely unknown mode of interaction of the solar wind with a planet.

V. Infrared Astronomy (Neugebauer and Leighton)

The infrared program has mainly concentrated on the use of photometry and spectroscopy at conventional telescopes to study extragalactic objects and the very red stars found in the recently published Caltech infrared sky survey. The 62" infrared telescope was used to continue monitoring the red sources previously found on the survey and to select the reddest of those found for further study.

VI. X-Ray and Gamma-Ray Astronomy (Garmire and Riegler)

A re-calibration of the OSO-III prototype gamma ray detector is complete and the data are being reduced. The Goddard Space Flight Center gamma ray

detector is being calibrated in the same gamma ray beam to provide a better check on the absolute gamma ray flux.

The detectors aboard the Nike-Tomahawk flight 18.71 worked successfully during the October 4, 1969 flight. A large low energy particle flux was detected and severely limited the study of the x-ray background. A multi wire chamber has been constructed for x-ray polarization studies and measurements of its properties are being made. A crossed wire proportional counter with 1 mm x-y resolution is being constructed for use at the focus of x-ray telescopes. Theoretical calculations of line formation including electron scattering at 10^7 ^{o}K and above are being undertaken.

FURTHER DESCRIPTION OF ACTIVITIES

I. Cosmic Rays (R. Vogt, E. C. Stone, K. Beuermann, and J. Fanselow)

The pαe experiment

The major activity on this project centered around the preparation and execution of a series of balloon flights with the 1969 Skyhook program at Fort Churchill, Manitoba. These flights were of particular importance, since they were coordinated with this group's observations with an essentially identical detector system aboard the polar orbiting OGO-6 satellite, launched 5 June 1969. A flight log of the balloon observations is given in Table I. The Caltech instrument worked successfully on all flights. Among the objectives of the simultaneous balloon and satellite observations are:

1. A direct measurement of the spectra of atmospheric secondary particles from a direct intercomparison of the satellite and balloon data. The problem of the corrections of cosmic-ray data for atmospheric secondaries has plagued balloon-borne observations for many years, and the analysis of results from many experiments will benefit greatly from the removal of existing uncertainties. In contrast to earlier opportunities for satellite-balloon correlations, the Caltech instruments have a sufficiently large energy range so that balloon derived spectra, which have undergone an energy shift due to ionization loss in the residual atmosphere, and satellite spectra overlap.
2. Studies of the properties of the magnetosphere by simultaneous measurements at different locations in the magnetosphere.
3. Direct measurements of the splash albedo on balloon flights (with the detector system pointing in the anti-zenith direction) as an aid in the interpretation of satellite data.

Data anlaysis of pαe data is continuing.

The $e^{\pm}$ magnetic spectrometer

The activities on this project were concentrated upon the preparation and execution of balloon observations, calibrations on the Caltech synchrotron, the design and construction of instrument modifications, and the analysis of flight data.

Four successful launches under the 1969 Skyhook program at Fort Churchill, Manitoba were accomplished. The Caltech instrument performed successfully on all flights. A flight log is presented in Table II. Two of the successful launches were with valved balloons, allowing a time-altitude profile optimized for the derivation of atmospheric secondary corrections. A typical altitude profile consisted of about 5 hrs. exposure at maximum float altitude, a 2 hr. gradual descent to a lower altitude, and a subsequent level float for another 3 hrs. or more.

The results of calibrations on the Caltech synchrotron for the effects of γ-ray induced instrumental background were used to improve the analysis of the $e^{\pm}$ observations from the 1968 flight series. Improved results were presented at the XI International Conference on Cosmic Rays, Budapest.

The effects of the diurnally varying geomagnetic cutoff occurring near Fort Churchill are evident in Fig. 1, which clearly shows a large difference in the positron and negatron spectra measured during the respective day and nighttime periods. The existence of the day-night effects at even the lowest energy interval of the spectrum shows that the nighttime geomagnetic cutoff was below the full energy range of the instrument. The nighttime data, after subtraction of atmospheric secondaries, therefore represent the extraterrestrial electron flux. The critical nature of the corrections for atmospheric secondaries is evident from Fig. 2, showing the separation of locally measured fluxes in the atmosphere into primaries and secondaries on the basis of this group's correction technique. A separate paper on the nature of the secondary electron component in the atmosphere is near completion.

In Fig. 3b this group's measured 1968 primary cosmic-ray positron fluxes are shown together with those obtained by Fanselow, Hartman, Hildebrand, and Meyer in 1965 and 1966. In an earlier paper (Phys. Rev. Letters 22, 412, 1969), this group deduced the absolute solar modulation of positrons in 1968 for energies between 12 and 220 MeV from a comparison of its measured positron spectrum with an interstellar equilibrium spectrum calculated by Ramaty and Lingenfelter for positrons originating in cosmic ray collisions with interstellar matter (curve e_s^+). In the energy range of this group's measurements, the interstellar flux is reduced significantly near Earth, and the modulation appears strongest at $\sim$ 70 MeV. The diffusion-

convection theory of solar modulation in a simple form predicts a modulation function

$$F(R) = \exp\left[-\eta/\beta\, f(R)\right]$$

where R is the rigidity, βc is the particle velocity, and η is a rigidity independent parameter characteristic of the state of the interplanetary medium. In our earlier paper we suggested on the basis of our measured positron spectrum that

$$\begin{aligned} f(R) &= R \quad \text{for } R > R_o = 70 \text{ MV} \\ f(R) &= R_o^2/R \quad \text{for } R < R_o = 70 \text{ MV} \end{aligned} \tag{1}$$

and the parameter $\eta = 0.5$. We discussed the consequences of this model, which makes explicit the decreasing modulation at low rigidities implied by our data. Although it is a good fit to our data, it is not the only possible fit.

Nucleonic data indicate that

$$\begin{aligned} f(R) &= R^{\delta} \quad \text{for } R > R_o \\ f(R) &= R_o \quad \text{for } R < R_o \end{aligned} \tag{2}$$

with $\delta \approx 0.5 - 1$ and $R_o \approx 0.3 - 1$ GV. Using this functional form, Fanselow et al. have made a fit to their positron data above 173 MV with $\delta = 1$, $R_o = 0.3$ GV, and $\eta = 0.6$ GV. The modulated spectrum derived from the interstellar spectrum with these values is shown as curve (a) in Figure 3b. While adequate at energies above 200 MeV, this set of parameters is unsatisfactory (χ^2 probability $P << 0.01$) for the lower energies covered by our measurement. A better fit to our data is obtained with an $R_o = 175$ MV, shown as curve (b) in Figure 3b ($P = 0.28$). This model implies a strong modulation below 20 MV in contrast to the decreasing modulation given by Equation (1). Simnett and McDonald have pointed out that their measured electron spectrum between 2 and 20 MeV is compatible with a sole origin in the galactic knock-on component if solar modulation is insignificant at these energies. Since our data clearly indicate a strong modulation near

100 MeV, only a decreasing modulation at lower energies, as exemplified by Equation (1) would be consistent with the knock-on hypothesis. However, the statistical accuracy of our data does not allow us to dismiss solar modulation as described by Equation (2). Both models adequately describe the pronounced modulation evident in the region near 100 MeV.

A significant modification of the instrument is near completion. Its main features include the addition of a gas Čerenkov-counter (see Fig. 4), which will contribute to a reduction of γ-ray induced background, and with the inclusion of a larger (2.3KG) bending magnet will allow the extension of the instrument's energy range to about 800 MeV. The modified version of the $e^{\pm}$ spectrometer thus in future flights will cover essentially the whole energy range where significant solar modulation of the electron flux occurs.

The fast logic, high intensity version of the OGO-6 detector system

The OGO-6 and $p\alpha e$ detector systems use a range versus energy-loss technique for the measurement of proton and helium energy spectra. Their electronic logic system is a relatively slow system, completely adequate for their intended use in space, but not suitable for the high beam intensities experienced during calibrations on particle accelerators. Corrections for nuclear interactions in the range absorber stack however are important, and their calculation must be verified by direct calibrations. In order to make accelerator calibrations with the desired accuracy, a range telescope physically equivalent to the OGO-6 instrument has been constructed, using plastic scintillators instead of solid state detectors (see Fig. 5). This change makes possible the use of standard high energy physics instrumentation. The ability to handle high fluxes will allow the accumulation of statistically significant data in reasonable machine-time intervals.

Construction of the acceleration detector system and circuitry is complete, testing and integration and computer programming are underway, and the first accelerator runs on NASA's REL synchrocyclotron are scheduled for late January 1970.

Table I. Fort Churchill Flight Series 1969 (pae):

Caltech Flight No.	69C1P	69C2P	69C3P	69C4P	69C5P
Raven Flight No.	1255-N	1259-N	1260-N	1263-N	
Launch Date	6/14/69	6/18/69	6/21/69	6/25/69	7/1/69
Launch Time (UT)	03:30	05:08	04:03	06:43	04:14
Start Float (UT)	11:10	09:15	08:37	09:20	08:10
Termination (UT)	19:42	20:25	18:47	23:30	21:05
Typical Float Altitude (g/cm^2)	2.6	1.9	1.9	3.7	3.4
Detector Orientation	Zenith	Zenith	Zenith	Anti-Zenith	Zenith

Table II. Fort Churchill Flight Series 1969 ($e^{\pm}$)

Caltech Flight No.	69C1M	69C2M	69C3M	69C4M
Raven Flight No.	1257-N	1261-N	1270-N	1276-N
Launch Date	6/14/69	6/29/69	7/5/69	7/17/69
Launch Time (UT)	21:34	22:51	23:09	02:59
Start Float (UT)	01:16	01:13	02:00	05:53
Termination (UT)	14:34	19:55	14:53	20:29
Float Altitudes (g/cm^2)	3.4 (5.5 hrs) 18 (3.5 hrs)	3.3 (4.5 hrs) 30 (11 hrs)	2.7	2.7

Differential energy spectra of the raw flux of positrons and negatrons (July 1960) during the nighttime interval (2.4 g/cm^2) and during the daytime interval (2.3 g/cm^2)

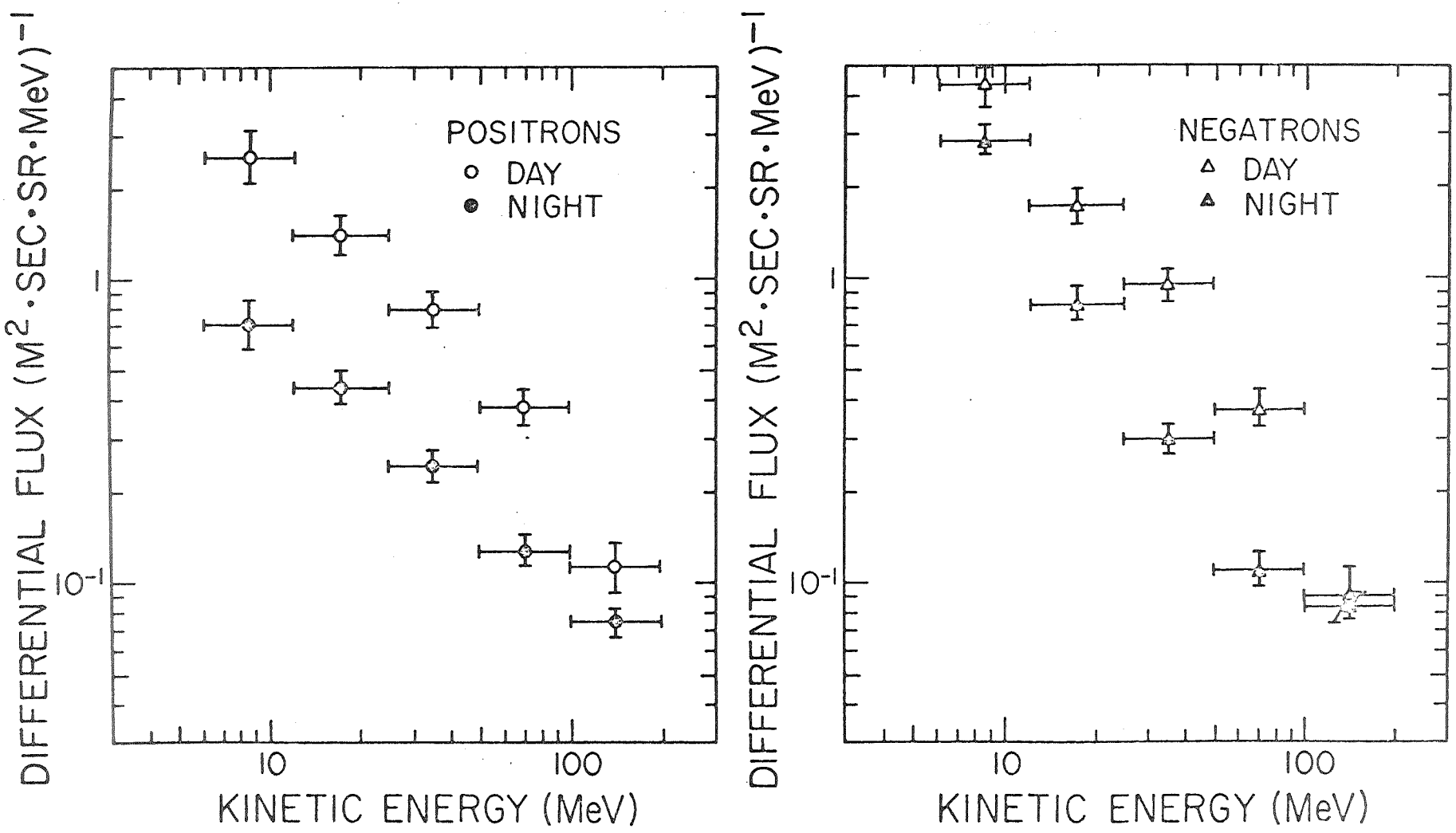


FIGURE 1

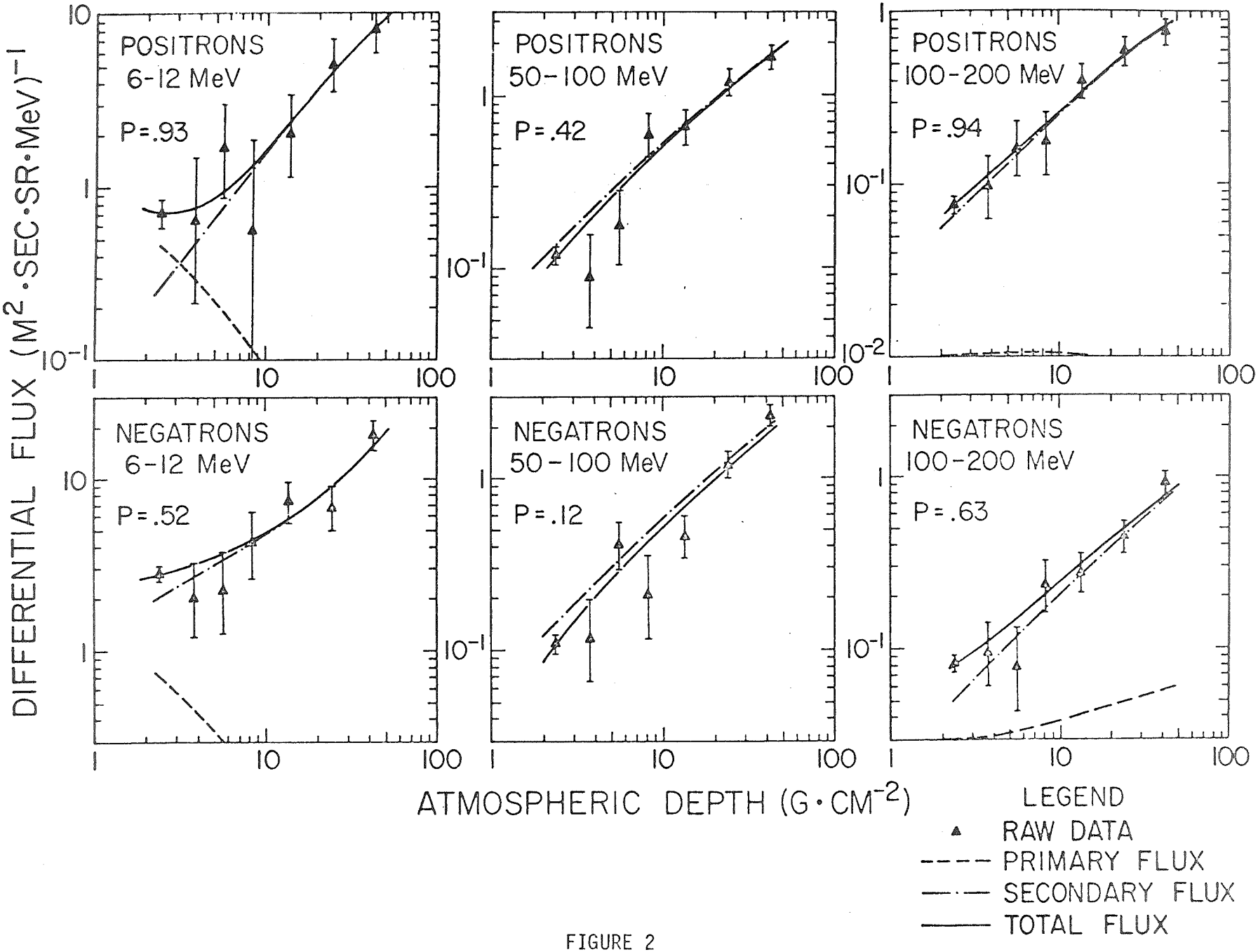
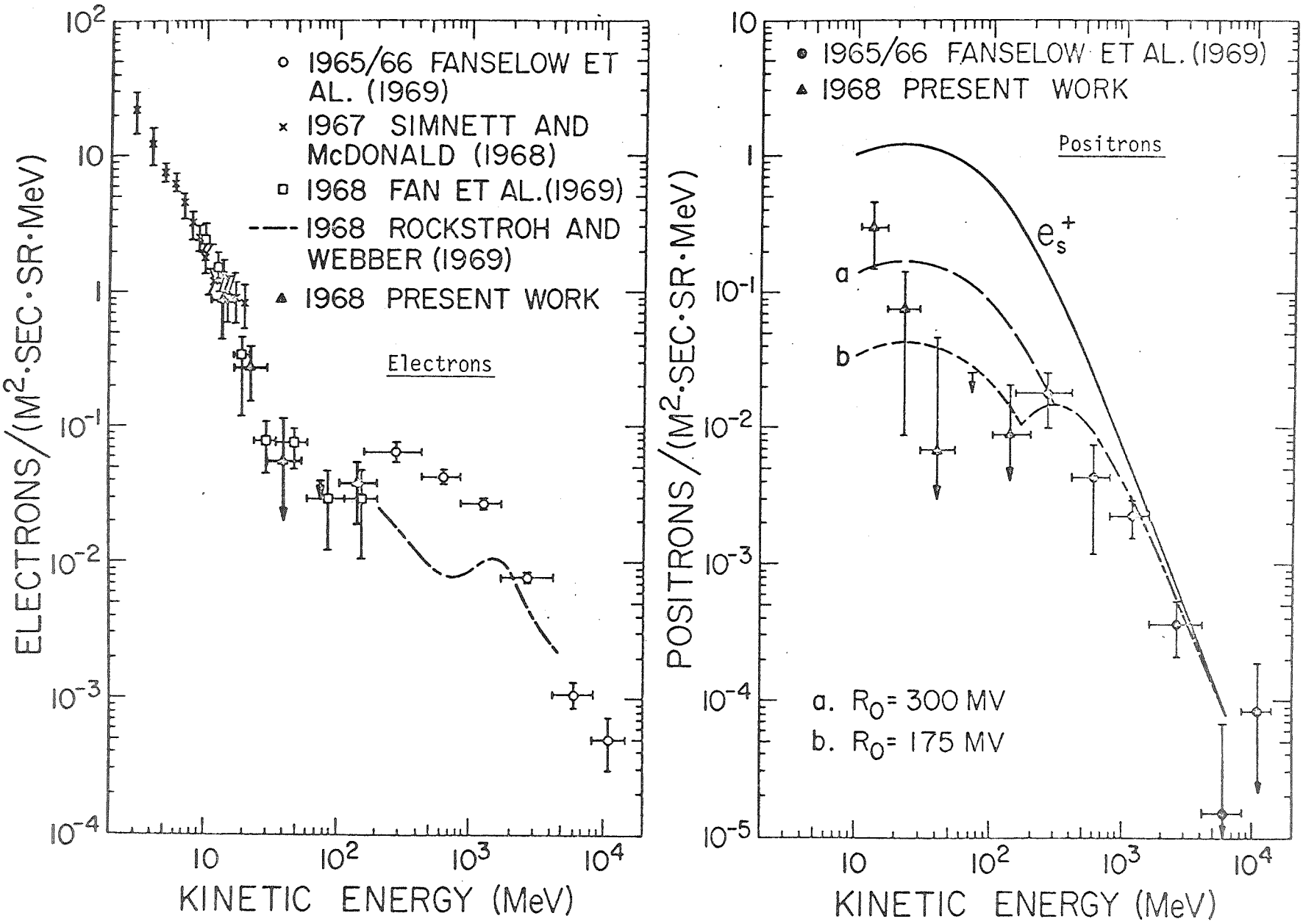

POSITRONS
6-12 MeV
P=.93
POSITRONS
50-100 MeV
P=.42
POSITRONS
100-200 MeV
P=.94
NEGATRONS
6-12 MeV
P=.52
NEGATRONS
50-100 MeV
P=.12
NEGATRONS
100-200 MeV
P=.63
DIFFERENTIAL FLUX (M^2·SEC·SR·MeV)$^{-1}$
ATMOSPHERIC DEPTH (G·CM^{-2})
LEGEND
RAW DATA
PRIMARY FLUX
SECONDARY FLUX
TOTAL FLUX

FIGURE 2



3a

FIGURE 3

3b

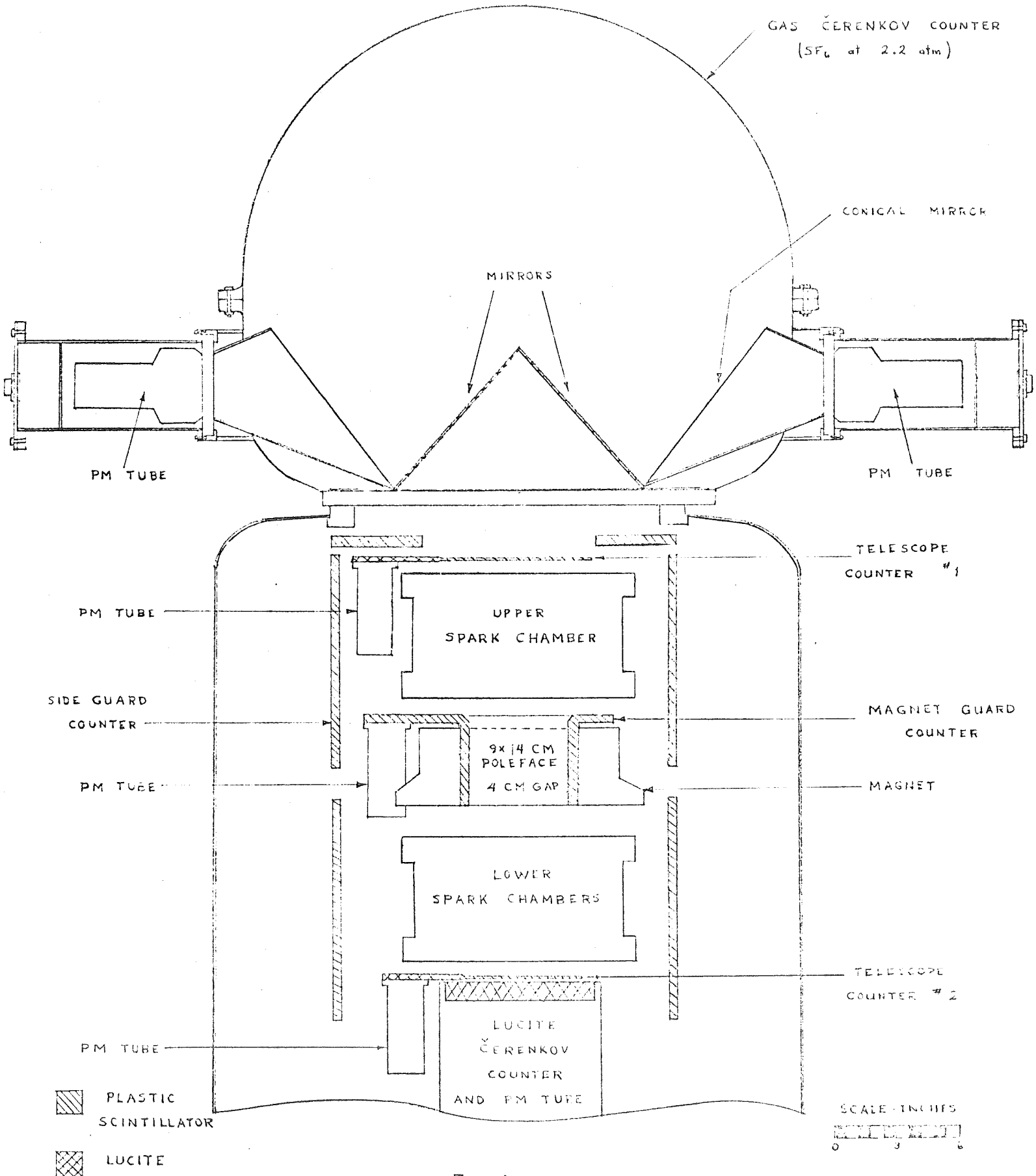

GAS ČERENKOV COUNTER
(SF_6 at 2.2 atm)
CONICAL MIRROR
MIRRORS
PM TUBE
PM TUBE
TELESCOPE COUNTER #1
PM TUBE
UPPER SPARK CHAMBER
SIDE GUARD COUNTER
MAGNET GUARD COUNTER
9x14 CM POLEFACE
4 CM GAP
PM TUBE
MAGNET
LOWER SPARK CHAMBERS
TELESCOPE COUNTER #2
PM TUBE
LUCITE ČERENKOV COUNTER AND PM TUBE
PLASTIC SCINTILLATOR
LUCITE
SCALE - INCHES
0
3
6

FIG. 4

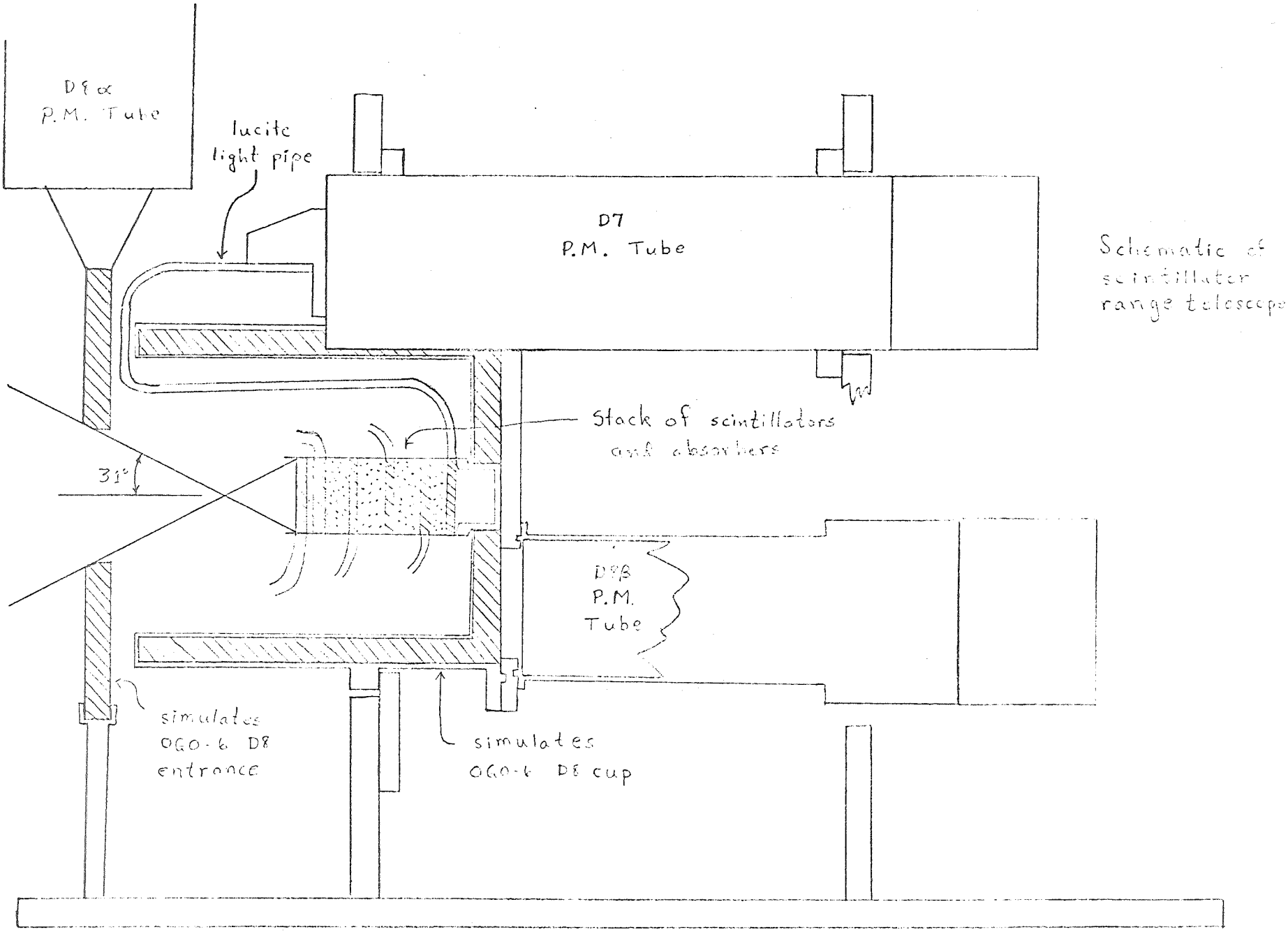

D8 α
P.M. Tube
lucite
light pipe
D7
P.M. Tube
Schematic of
scintillator
range telescope
Stack of scintillators
and absorbers
31°
D8β
P.M.
Tube
simulates
OGO-6 D8
entrance
simulates
OGO-6 D8 cup

FIG. 5

II. Cosmic Rays (H. V. Neher)

Activities for the six month period 1 April to 30 September 1969 were chiefly concerned with further analysis of the data from the polar orbiting satellites, OGO-II and OGO-IV. Much of the results from these instruments was incorporated into the thesis of Michael George, who received his Ph. D. degree in June of this year. George has submitted a paper for publication covering the results of his research on the intensity of cosmic rays in the lower atmosphere. He has also nearly completed two other papers covering some of the results obtained from the two above mentioned satellites. These will be submitted for publication soon. Work is continuing on the further analysis of the data from these satellites.

III. Interplanetary Fields and Plasmas (L. Davis)

The analysis of the Mariner V magnetometer and plasma data has been continued; in particular, study shows that a substantial part of the fluctuations are not convected structures, as the Goddard experimenters urged, but are propagating waves. The Mariner V Plasma Group has made available a more recent reduction of their data that includes the proton temperature and all three components of the plasma velocity. Earlier it had been shown that the fluctuations in the radial components of the magnetic field and plasma bulk velocity were well correlated about 30 percent of the time. Now it has been demonstrated that all three components are well correlated in just the way required if they are Alfvèn waves and that at least 50 percent of the time a significant part of the observed fluctuations are of this character. Such waves are much more prominent when the gas temperature is high suggesting that their generation might be connected with a high β field aligned pressure anisotropy.

At the time the Mariner IV magnetometer observations were made near Mars in 1965 it was recognized that two features seen were suggestive of a shock wave surprisingly close to Mars. It was also possible that these features were unusual examples of the structures sometimes seen in interplanetary space. In the absence of any confirming evidence, there was no real basis for arguing that Mars had a bow shock. The partial failure of the plasma probe early in the mission meant that the plasma data seemed

unavailable as a check. Recently John Davis at MIT has succeeded in determining some of the properties of the plasma near Mars and has found two features in the plasma that are best explained by a shock. although they do not require one. E. J. Smith and L. Davis have compared this plasma data with their magnetometer data and with the combined observations made by Mariner V near Venus and have found that if the undisputed Venus shock is scaled to the radius of Mars instead of to that of Venus, both plasma features and both magnetometer fall as closely as can be expected at the predicted shock crossings. Thus it seems likely that, as in the case of Venus, the solar wind approaches within a few hundred kilometers of the surface on the sunward side where it is probably stopped by a highly conducting ionosphere. If Mars has any intrinsic magnetic field at all, it must be small and should be looked for in the wake region. It would be very interesting to learn if Mars has a high density ($\sim 10^3$ electrons/cm^3) wake of the kind suggested for Venus by the dual frequency occultation data. Further study of this type of interaction both at Venus and at Mars would be very profitable scientifically.

Two papers were presented by L. Davis at the General Assembly of the IAGA in Madrid in September, 1969. One reviewed the interaction of the solar wind with Venus and Mars. The other, a paper by Dolginov, Eveshenko and Davis, compared Venera 4 and Mariner 5 observations made when the two spacecraft were about 5×10^5 km apart just before and as Venera 4 entered the wake of Venus. A number of common features were observed by the two spacecraft while both were in interplanetary space. It seemed clear that Venera 4 had a spacecraft field of from 5 to 10 gammas on each axis. There was some indication that part of the features seen by Venera 4 in magnetosheath region were associated with interplanetary features seen by Mariner 5, but there is so much complicated structure in the magnetosheath region that connections cannot be established with any confidence.

IV. Theoretical Astrophysics (R. F. Christy)

The analysis of calculations on Cepheid models has led to a number of useful general relations between the parameters of the models (and of the stars they represent) and observables. These relations are summarized below.

$$\text{Period of fundamental} = 0.021 \frac{(R/R_o)^{1.76}}{(M/M_o)^{.72}} \quad \text{days}$$

$$\text{Shortest Period of fundamental vibration} = .067\ (L/L_o)^{0.56} \quad \text{days}$$

Period-Luminosity-Mass-Color relation

$$- M_{bol} = 2.84 \log P_F + \log T_e + 2.05 \log M/M_o - 37.58$$

High temperature boundary of instability

$$\log T_e = 3.827 - 0.057 \log P_F$$

The work of summarizing results on pulsation is continuing. Three lectures on this work were given at the third Summer Institute for Astronomy and Astrophysics at Stony Brook June 18 - July 16, 1969. In addition, I attended a conference on pulsars arranged by the Aspen Center for Physics at Aspen in August and the first Sierra Conference on Astrophysics at Tuolumne Meadows in September.

V. Infrared Astronomy (G. Neugebauer and R. B. Leighton)

During the past report period the activities of the infrared group were concentrated on the data obtained with conventional telescopes. The main thrust of the group's activities were centered on

(a) the extra galactic objects - mainly the quasi-stellar sources and

(b) the continued studies of the objects found on the 2.2μ infrared sky survey.

The first study of the infrared properties of the quasars was completed in conjunction with J. B. Oke. Although it was found that in some quasars the infrared energy rose rapidly as for 3C273, a wide range in spectral slopes was found. In those objects where large optical variations are found, the infrared flux varies also; there seems to be no evidence for a change in color with phase. Continuous monitoring of these objects is in progress.

An attempt was also made to measure the quasars at 3.5 and 5μ. Unfortunately, although measurements were made, the data had too low signal to noise ratios to be significant.

Although the majority of the observing programs at the 200-inch telescope was washed out by bad weather, a few special objects were observed in conjunction with J. B. Oke. A note on the energy spectrum of a variable galaxy found by Zwicky is in press. Measurements of the Makarian objects and Zwicky compact galaxies, both of which are thought to be related to Siefert galaxies, are also in progress.

In a continuing study of the galactic center, the general area was mapped at the longer infrared wavelengths. It was determined that an extended region of about 16" was emitting with an energy distribution increasing at least to 20μ. The background radiation and the point source apparently follow the energy distribution of normal stars. This conclusion is strengthened by 2 - 2.5μ spectra of the point source and of the background obtained with the .5 meter Ebert-Fastie spectrometer. These spectra clearly show stellar features in the point source.

Photometer observations between 1 and 20μ of the infrared sources found on the 62-inch sky survey have been continued using the 60-inch and 100-inch telescopes. Emphasis has been placed on identifying and measuring the reddest of these stars, and also those sources which have OH radio emission. Since the brightness of many of the sources varies, several are now being observed on a regular basis to monitor the color changes. For statistical purposes a large number of sources which were found not to emit OH radiation are being measured to see whether a meaningful separation of the OH and non-OH sources can be made on the basis of their infrared colors.

A program of 8 - 14μ spectroscopy has been initiated using a circular filter wheel stepped in intervals of 0.18μ. Several very red stars have so far been observed. Two of these CIT6 and IRC +10216, do not show any evidence for the 8-11μ dust lump identified in other late type stars.

The source IRC +10216 which was identified in April is extremely interesting. It is an extended object located out of the galactic plane in an unreddened region. At 5μ it is the brightest source observed outside the solar system; at 2.2μ it varies by as much as 2 magnitudes with a time scale on the order of 600 days. Its energy distribution resembles that of a 650^{o}K black body and no spectral features have been observed in the wavelength range from 1-14μ. It is interpreted as being consistent with a galactic source surrounded by an optically thick dust shell.

The program of 1.6 and 2.2μ spectroscopy has been continued by A. R. Hyland and J. Frogel using the 0.5m Ebert-Fastie spectrometer with resolutions of 32.5 and 65Å. Observations have been made on approximately 40 nights on the Mt. Wilson 60- and 100-inch telescopes, and 3 nights on the 200-inch Hale telescope.

The study of the spectra of Mira variables throughout their cycles has been continued on a regular basis. Several of these stars show marked changes in the strength and shape of their H_2O and CO bands, while others show only minor variations. The group of S type stars under consideration all show very weak H_2O bands and strong CO bands, and thus appear to be more luminous than the normal M type Mira variables.

Spectra have been obtained of 10 OH sources which emit strongly at 1612 MHz. On the basis of these, most of the sources have been classified as Mira type variables, three appear to be M supergiants, while the spectrum of Orion point source has no spectral features from 2 - 2.5μ and appears to be due to an optically thick dust shell, similar to that proposed for IRC +10216.

Further spectra of very red stars identified from the 62-inch survey have been obtained for classification purposes. Several of these appear to show the effects of dust shell radiation and have very weak molecular bands, though the majority appear to be normal Mira variable stars.

Analysis of the infrared spectroscopy and photometry of the Orion Nebula (M42) and the planetary nebulae IC 418 and NGC 7027 is continuing. Values have been obtained for the reddening, electron temperature, and electron density for these nebulae. In addition, a helium abundance has been obtained for M 42 from the 1.70μ He II line. An unexpected continuum excess has been discovered in the H and J bands. An analysis of this excess as well as a determination of dust properties from the previously known longer wavelength excess is in progress.

In addition to the study of infrared stars which have turned out to be OH emitters, a program is underway to map areas, such as Orion, which contain complex H II regions and are known OH emitters. In every such object examined in detail an infrared source with a color temperature near 500 - 600°K has been found, although in most cases the IR sources have been separated from the OH sources. The source in NGC 6857, which was found recently, again can be represented by a 500°K black body; it shares the distinction, with the Orion infrared source, of apparently being coincident with the OH emitting source.

With the completion of the survey, the 62" telescope was used mainly in a monitoring mode. Early in the summer a new epoxy mirror was installed in the telescope; unfortunately the image quality is apparently not greatly improved over that of the previous mirrors.

During this year the filters used with the 62" were altered so that photometric measures at 0.8, 1.6, 2.2, and 3.4μ could be obtained. These observations were the basis for the selection of objects which were observed photometrically at conventional telescopes. About 440 of the reddest stars have been observed with the telescope on a bi-monthly basis since their discovery on the survey. Variations are typically on time scales of years and some objects vary by as much as 2 magnitudes at 2.2μ. A sizeable effort was made to use the 62" in a 5μ or 10μ survey. At the present time, such a survey is felt to be too severely limited by sky noise to be productive.

VI. X-Ray and Gamma-Ray Astronomy (G. Garmire and G. Riegler)

The data reduction of the OSO-III gamma ray detector is nearly complete. The instrument operated without any failure for about 2-1/2 years and has been turned off as of about October 6, 1969. Figure 1 shows the results of several cuts across the galactic plane. An interesting feature which appears to be significant is the large displacement of the gamma ray intensity to the south of the galactic plane in the longitude band $150^{o} \leq \ell^{II} \leq 210^{o}$. This feature corresponds to an extension of the hydrogen distribution to the south and indicates that a significant flux of cosmic rays exists away from the plane of the galaxy.

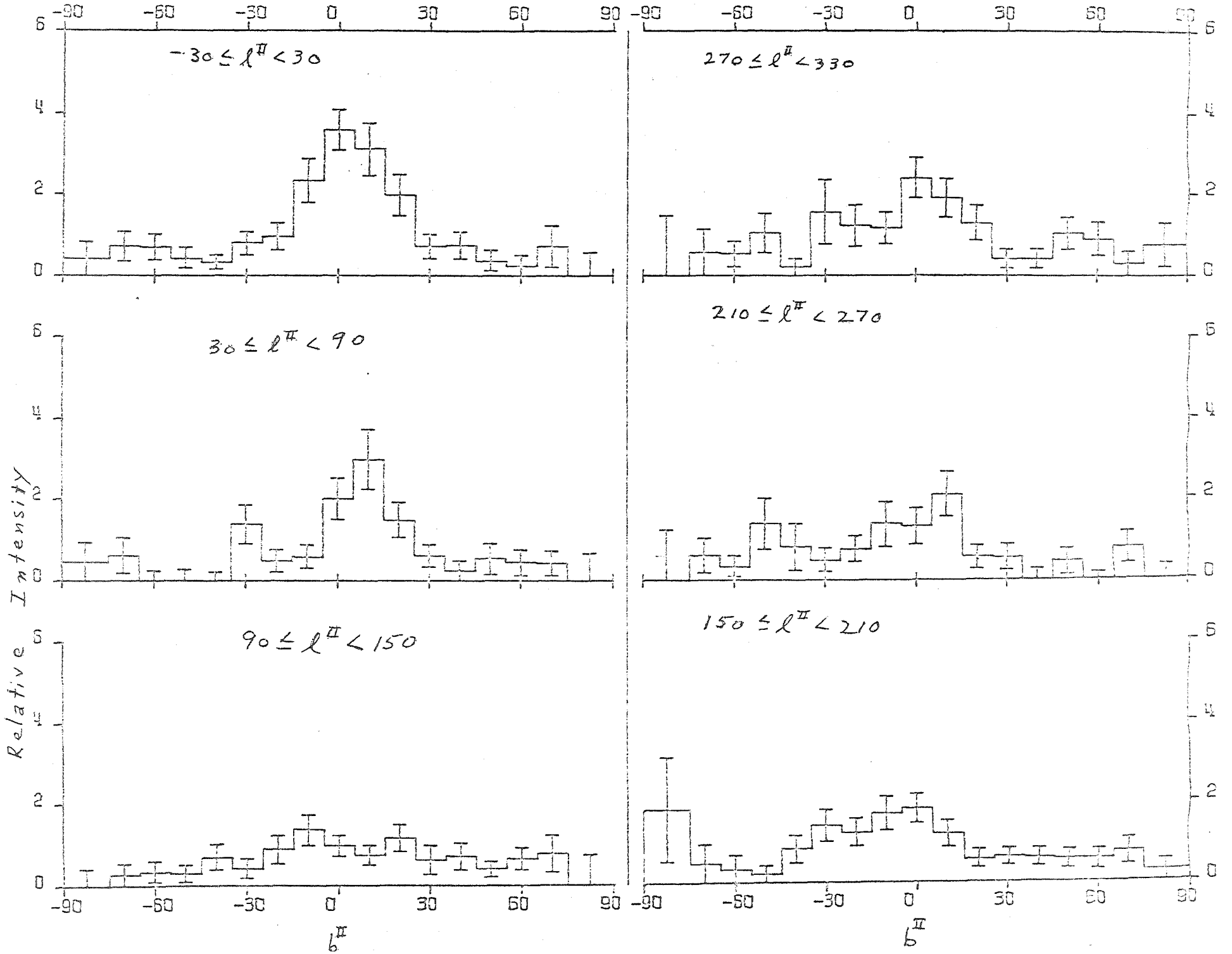
A preliminary analysis of the recalibration data shows that the prototype instrument differs considerably from the previous calibration made on the flight instrument. The reason for the difference is not clear. The flight calibration was made under a good deal of pressure and an error could have been made. In view of the condition of the prototype detector it is not likely to be more efficient than the flight unit. At present we are finding that the prototype instrument is more efficient by nearly a factor of two than the flight detector and conclude probably an error was made in the flight calibration.

The detector system flown aboard a Nike-Tomahawk rocket from Wallops Island on October 4, 1969 operated well. Unfortunately, a large flux of low energy particles was present and produced a large detector background. The data for charged particle identification is quite unambiguous in that coincidence pulses between proportional counter chambers were recorded and a large flux anisotropy peaking perpendicular to the local magnetic field was observed. Reduction of the x-ray data is just beginning and the extent of the contamination of the x-ray background observations will need a thorough analysis. The low energy particles were most likely electrons above about 15 keV. The electron flux was quite altitude dependent, increasing rapidly with increasing altitude.

A wire proportional chamber is under construction. The chamber is constructed with individual wires forming the ground planes for the anodes and perpendicular to the anodes. By amplifying the negative signal on the anodes and the positive signal on the ground wires an x-y position of where the interaction occurs can be determined. The chamber under construction has 0.25 inch resolution, and a resolution of 0.04 inches seems possible.

A chamber such as this can be used at the focus of an x-ray telescope or as the detector for an x-ray microscope. An x-ray microscope can be constructed using a "point" source of x-rays, a sample at a distance, S, and the proportional chamber at a distance, d. The magnification is (d/S) and is limited only by technical problems of intensity and how well a point source of x-rays can be constructed.

Theoretical calculations of line formation including electron scattering at temperatures over 10^7 ^oK are being started. The very complicated program used to compute the continuum spectrum by E. Loh is being studied to determine whether simplifications can be made without affecting the accuracy appreciably. The program will be to compute line profiles and intensities for spherical and shell-shaped gas clouds.


$-30 \leq \ell^{II} < 30$
$270 \leq \ell^{II} < 330$
$30 \leq \ell^{II} < 90$
$210 \leq \ell^{II} < 270$
$90 \leq \ell^{II} < 150$
$150 \leq \ell^{II} < 210$
Relative Intensity
b^{II}
-90 -60 -30 0 30 60 90
0 2 4 6

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